



Upgrading Fuel Oil to Euro V Gasoline

Residue Hydrotreating and RFCC

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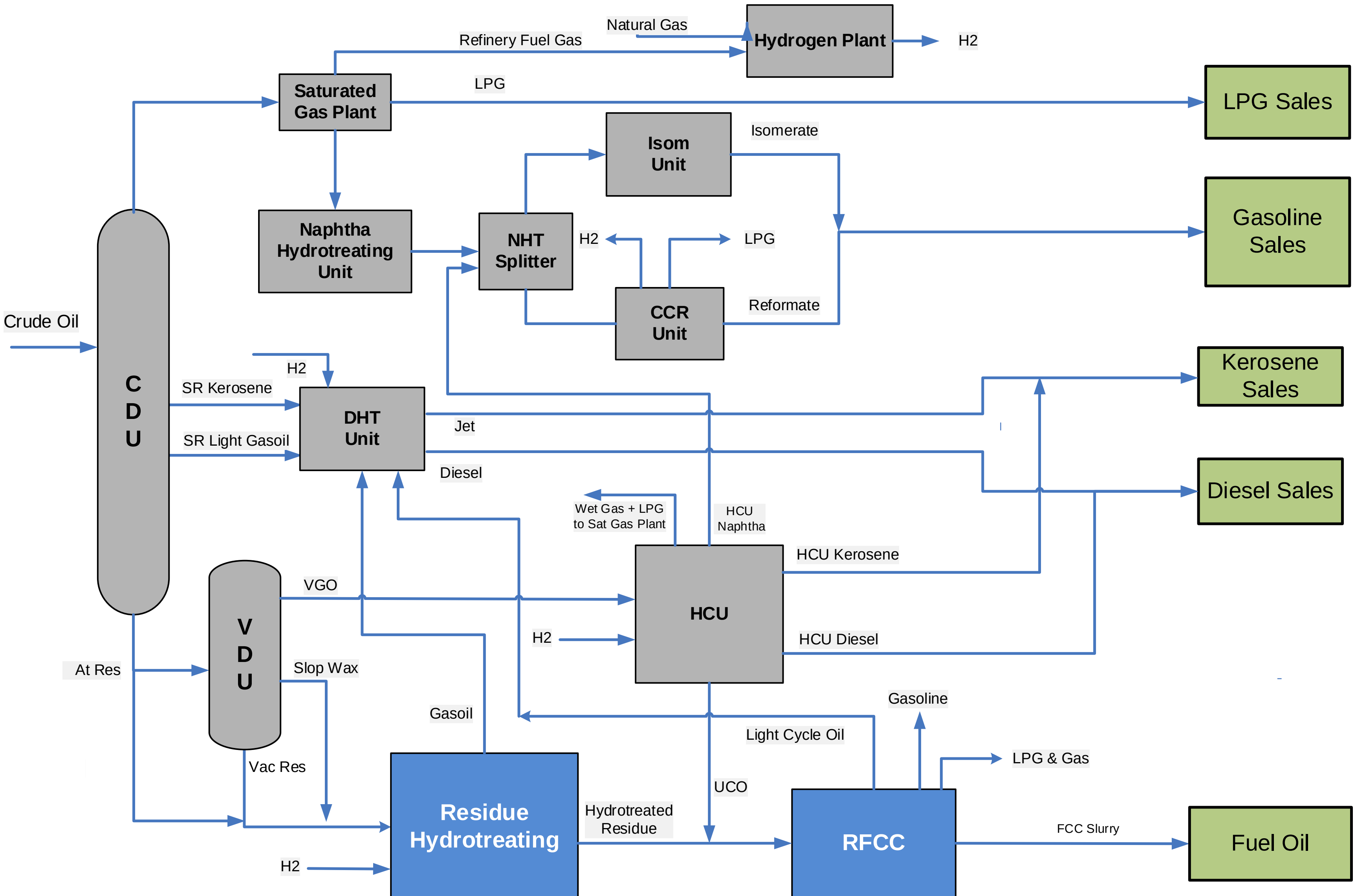
Honeywell UOP

RCD Unionfining – RFCC Complex



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Agenda

Challenges in upgrading residue streams

Impact of heavy feeds on RFCC operation and conversion

RCD Unionfining™ process enables efficient downstream upgrading

UOP RFCC Process: technology solution for economic upgrading of residue to gasoline

Residue Streams are Challenging to Process

- Contaminant levels increase with boiling range in most crudes
- Residue streams typically contain high sulphur, nitrogen, Conradson carbon, organometals and asphaltenes

Stream	Atmospheric Residue	Vacuum Residue
Sulphur, ppm wt	2.3	3.0
Nitrogen, ppm wt	**2600**	**4000**
Conradson Carbon, %wt	**8**	**16.3**
Ni + V, ppm wt	**83**	**164**
Asphaltenes, %wt	**1.5**	**3.1**

Key to success is managing pressure drop

Impact of Residue Feeds on RFCC Unit Operation

1. ***UOP K Factor:*** The K factor differentiates between the paraffinicity and aromaticity of the feed, and it indicates the crackability of the feed

2. ***Sulphur:*** Increases the sulphur content of the products

3. ***Nitrogen:*** Basic nitrogen compounds will neutralize acid sites on the catalyst causing temporary loss of catalyst activity and drop in unit conversion

4. ***Conradson Carbon:*** Increases coke yield and could limit the coke burn capacity

5. ***Metals Content:*** All metal contaminants have a negative impact on catalyst performance. Vanadium deactivates the catalyst by destroying the zeolite crystal structure. Nickel promotes dehydrogenation reactions

6. ***Hydrogen in Feed:*** drives conversion and higher propylene yields

Impact can be managed by residue hydrotreating

RCD Unionfining™ Process

- UOP’s licensed residue hydrotreating technology for processing highly-contaminated feedstocks such as AR, VR and DAO
- Combines commercially-proven process technology, proprietary catalyst systems and proprietary reactor internals
- Reduces the contaminant (sulfur, nitrogen, Conradson carbon, asphaltene and Ni+V) contents of feedstocks and adds hydrogen to produce:
  - low sulfur fuel oil
  - upgraded feedstocks for conversion units (FCC, RFCC, Coker, Hydrocracker)
- RCD Unionfining unit commercial experience:
  - First unit licensed in 1967
  - >30 units licensed with a combined capacity of >1,000,000 BPSD

RCD Unionfining Process – Commercial Experience

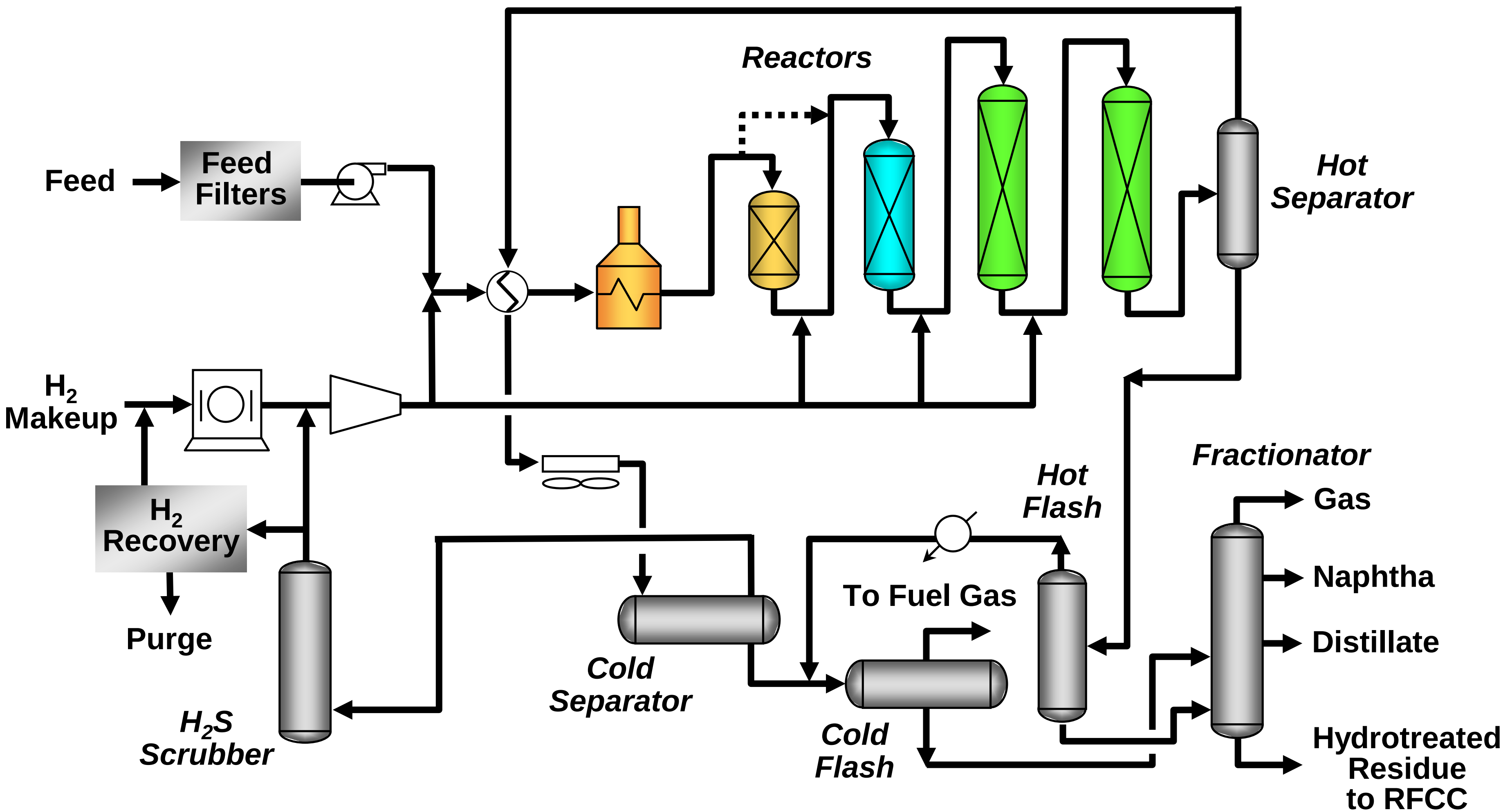
- Commercial flow schemes include:
  - Single- and two-stage configurations
  - Single- and parallel-reactor trains
  - Stripper or full fractionation configurations

- Feedstock qualities of commercial RCD Unionfining process units:
  - °API: 9 - 18
  - Sulfur: 3 - 5 wt%
  - Conradson Carbon: 5 - 15 wt%
  - Organometallics (Ni+V): 10 - 200 ppm wt
  - Viscosity: 25 - ~1000 cSt@100°C

- Operating conditions of commercial RCD Unionfining process units:
  - Throughput: 5600 - 75,000 BPSD
  - Pressure: 80 - 205 barg
  - LHSV: 0.10 - 1.2 hr^{-1}
  - Operating cycles: 6 - 24 months (typical economic optimum ~12 months)

Operating conditions tailored to each application

RCD Unionfining Process – Typical Flow Scheme

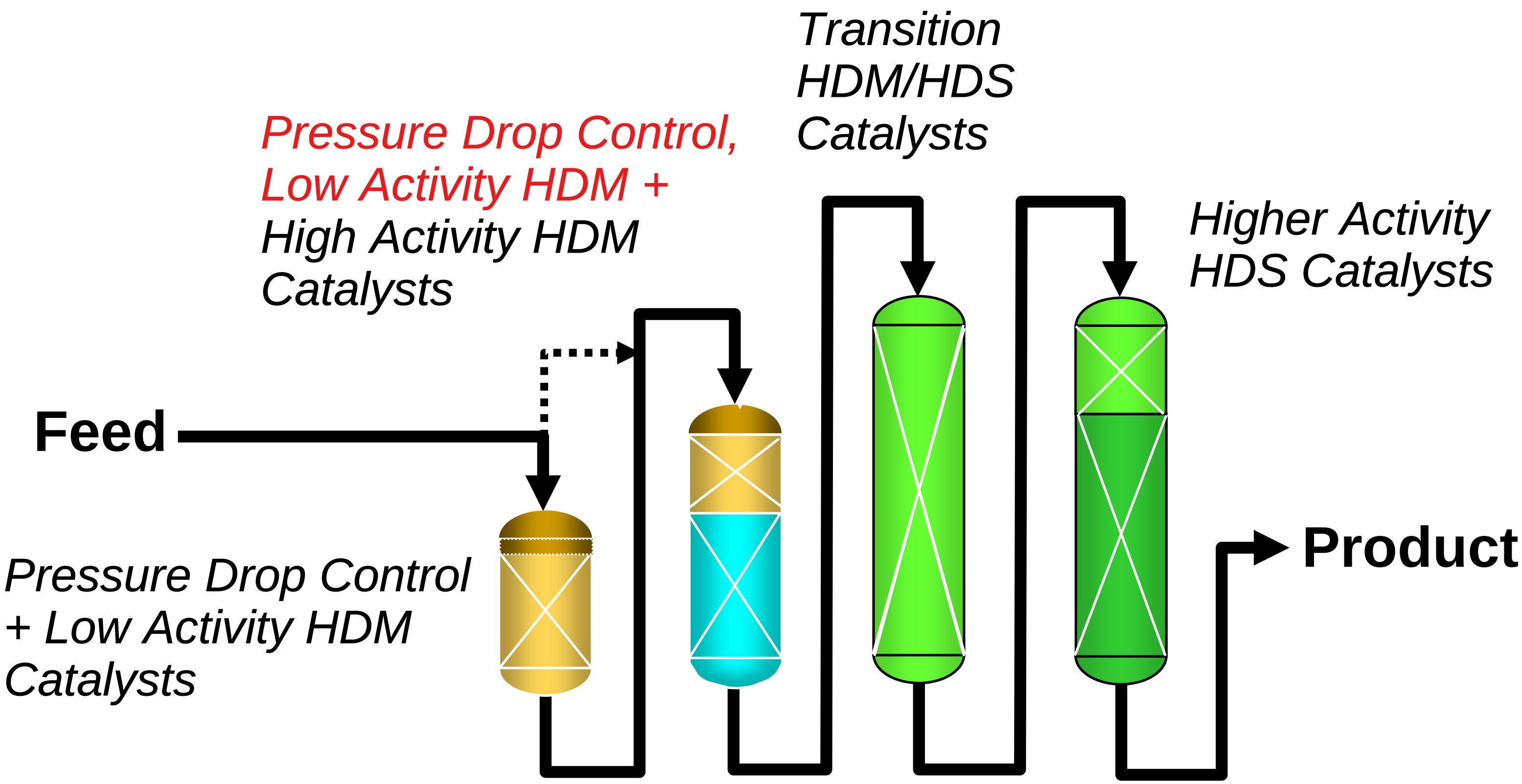


Number of reactors depends on specific service

Specialist Catalyst Systems

- Over 120 catalyst loadings
- Proprietary catalysts designed for specific functions:
  - Pressure drop control – high efficiency particulate traps
  - Metals removal / accumulation
  - Metals removal / desulfurization
  - Conradson carbon reduction
  - Desulfurization
- Pilot plant facilities available to verify estimated performance, produce product samples, etc.

Optimized Catalyst Loading



Tailored catalyst loadings optimise residue hydrotreating unit performance and economics

RCD Unionfining Process Summary

- RCD Unionfining Process enables efficient upgrading of residue streams via RFCC
  - Reduces metals, Conradson carbon, sulphur, nitrogen and asphaltenes
  - Adds hydrogen → higher RFCC conversion and gasoline yield

- Specialist process design & catalyst system required to achieve good cycle length

- Processing targets need to be optimised together with RFCC operation considering
  - Overall capital cost
  - Overall yields
  - Operating costs (including hydrogen & catalysts)

Agenda – Residue FCC

Economic Drivers for RFCC Units

Impact of heavy feeds on RFCC Unit conversion

UOP RFCC Process: meet economic objectives with technology solutions

RFCC Operating Modes

Distillates Mode RFCC

- Maximum LCO yield
  - Extremely Low Cetane Number ~ 19-20
  - Challenging to route LCO to EURO 5 diesel

Conventional RFCC (Fuels)

- Gasoline and LPG
  - 4-6 wt% propylene
  - 50-58 wt% gasoline
- Typical catalyst system and operating conditions

Fuels and Petrochemicals (Enhanced LPG)

- Gasoline/Alkylate/Petrochemicals
  - 6-12 wt% propylene
  - 38-48 wt% gasoline
- Catalyst system with ZSM-5 and modified operating conditions

Solution

Petrochemicals (High Propylene)

- 12+ wt% propylene
- Catalyst system with ZSM-5
- Optimized process conditions (pressure, temp, steam)
- Poor quality of naphtha & LCO - challenging to route to EURO 5 gasoline & diesel

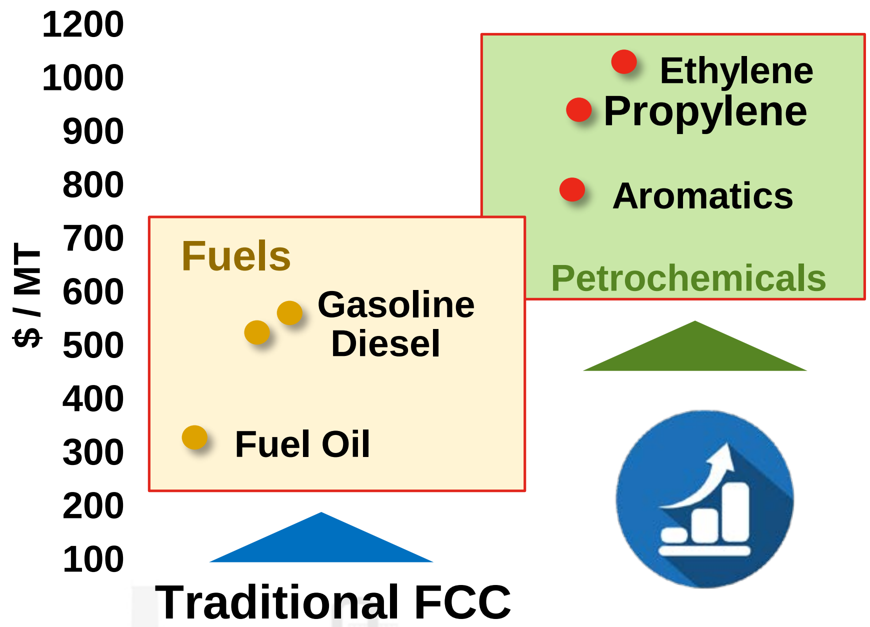
Distillate Mode: Cost to upgrade low cetane LCO negatively impacts economics

RFCC Drivers to Capitalize new Opportunities

UOP RFCC specifically designed to help maximize value by:

- Producing **higher value product – propylene**
  - Ability to produce **polymer grade propylene** (e.g.- 250+ KMTA from 2.5M MTA RFCC)
- **Simultaneously** helping to maximize RFCC naphtha as a gasoline blendstock whilst making propylene
- **Class V compliant with 95 RON (low enough aromatics to blend to gasoline)**
- Unmatched licensing experience
  - 295 units licensed
  - More than 50% of world-wide capacity
  - 70 years of design & operation feedback

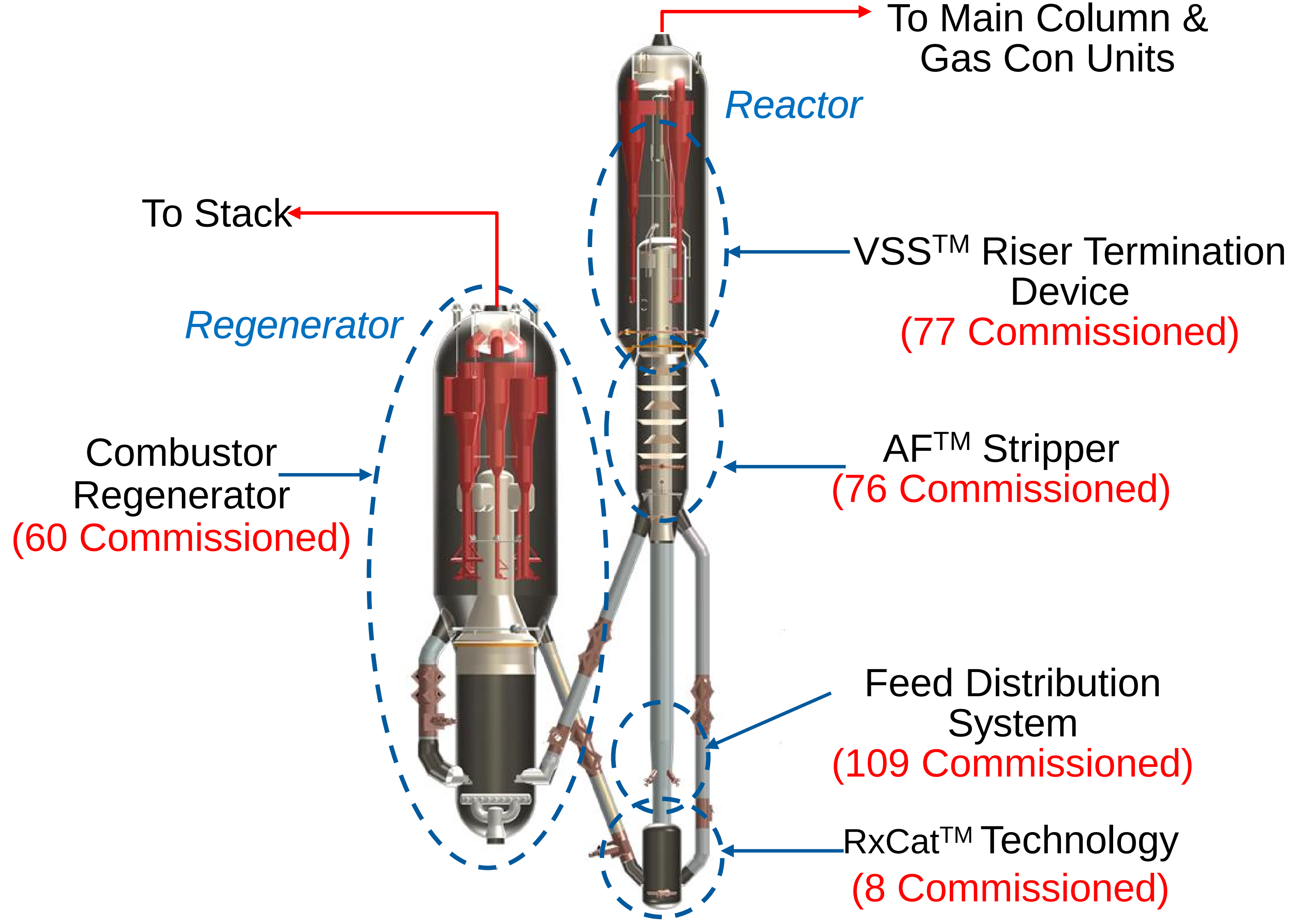
Product Prices, September 2017



Shift to petrochemicals adds significant value

Enhanced LPG RFCC significantly improves project economics

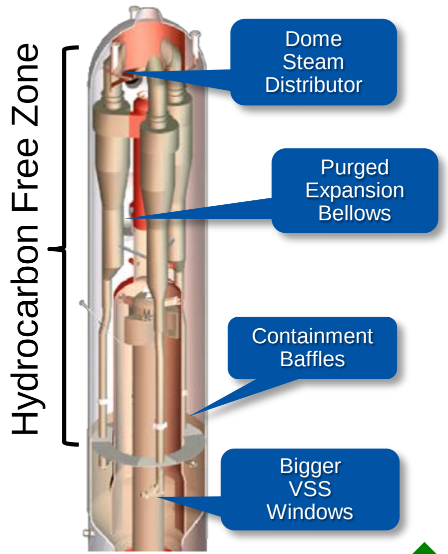
Best in Class FCC Technologies Maximize Processing Versatility and Yields



Fully commercialised technology

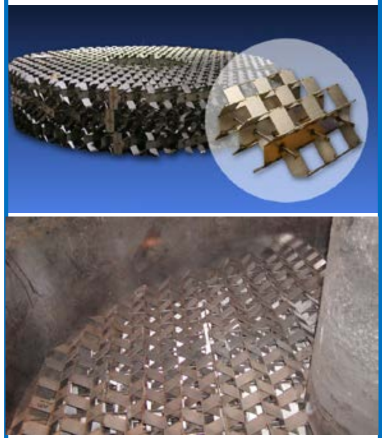
Technology options for improved yields and economics.

VSS™ Riser Termination



- Gasoline Selectivity
- Dry Gas, ΔCoke, Trg
- Improved Reliability
- 77 Commissioned

AF™ Stripper Packing



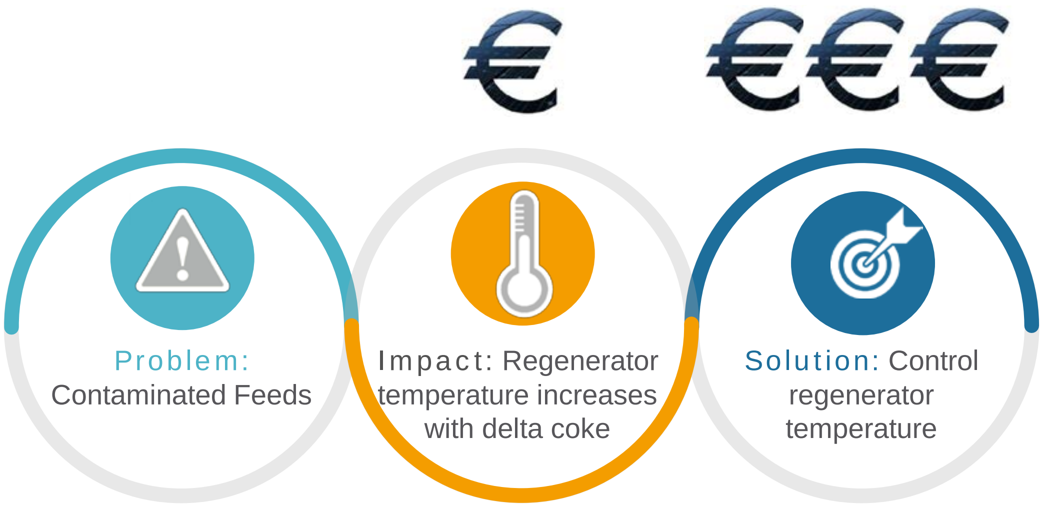
- Conversion
- Dry Gas, ΔCoke, Trg
- Improved Reliability
- Improved Ops Flexibility
- 14 Commissioned

Elevated Feed Distributors

- Conversion
- Gasoline Selectivity
- Dry Gas, ΔCoke, Trg
- Improved Reliability
- 109 Commissioned

UOP Technology Improves Performance and Operating Flexibility

Options Available for Handling Increased Coke Formation

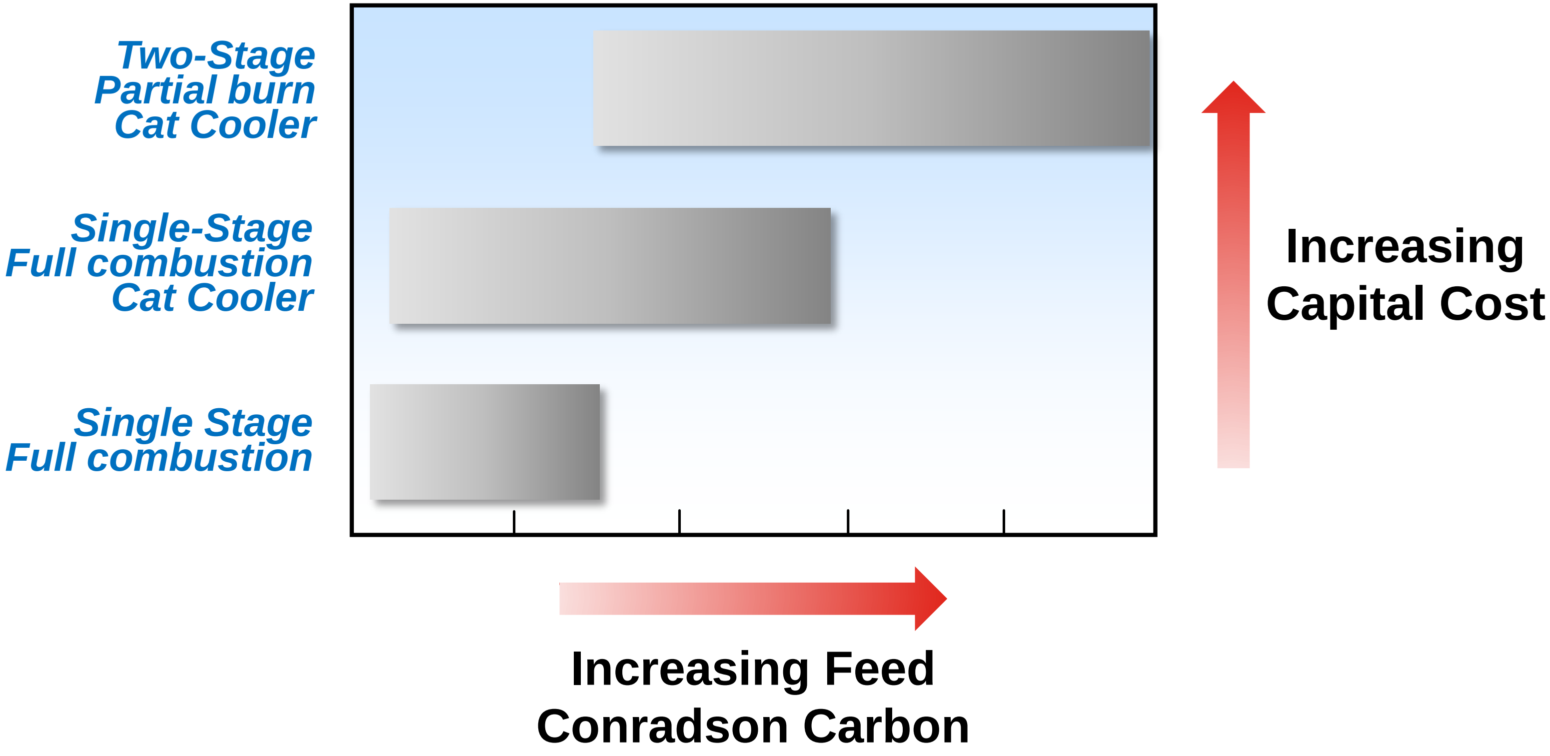


- High Delta Coke
- Catalytic coke
- Contaminant coke

- Reduces C/O and conversion
- Accelerated catalyst deactivation
- Decreased internal equipment working life
- Low product margins

- Inclusion of latest technology that minimize delta coke
- Catalyst cooler
- Partial combustion operation, application of Two-Stage Regenerator
- High product margins

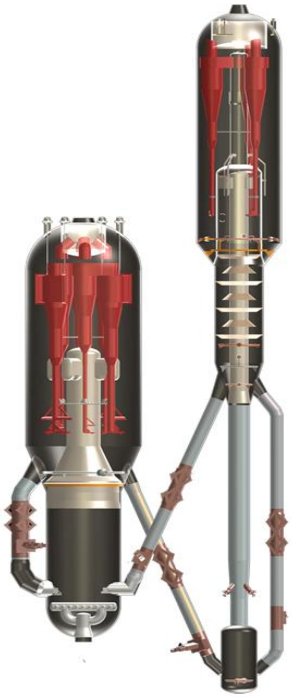
UOP's RFCC Regenerator Technology Portfolio



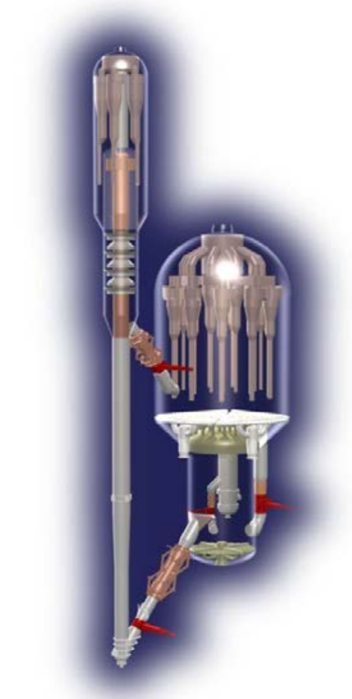
UOP Technology can process a wide range of feed Conradson Carbon

UOP's RFCC Regenerator Technology

Single Stage Combustor



Traditional Two Stage Partial Combustion



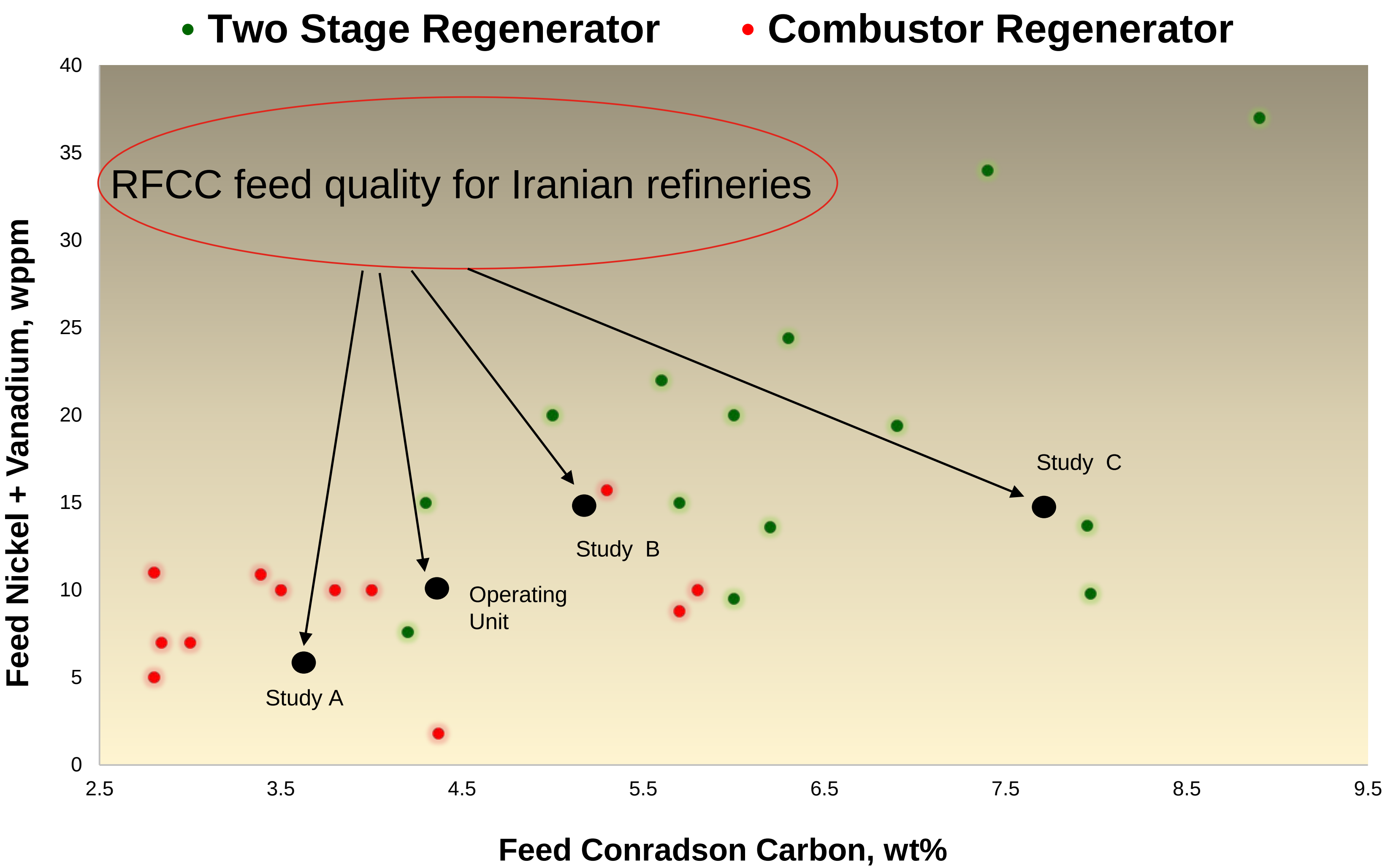
Single Stage – Combustor Operation

- Full combustion (Single Stage Combustor) is simpler approach
  - No CO Boiler required
  - Lower cost flue gas section
- Regenerator operating temperature managed with catalyst cooler
  - For temperature >732°C

Traditional Two Stage – Partial Combustion

- Partial mode of operation
- Compared to other Two Stage Regenerator style, UOP design offers:
  - Single flue gas line
  - Easier for power recovery

Significant Experience with Highly Contaminated Residue



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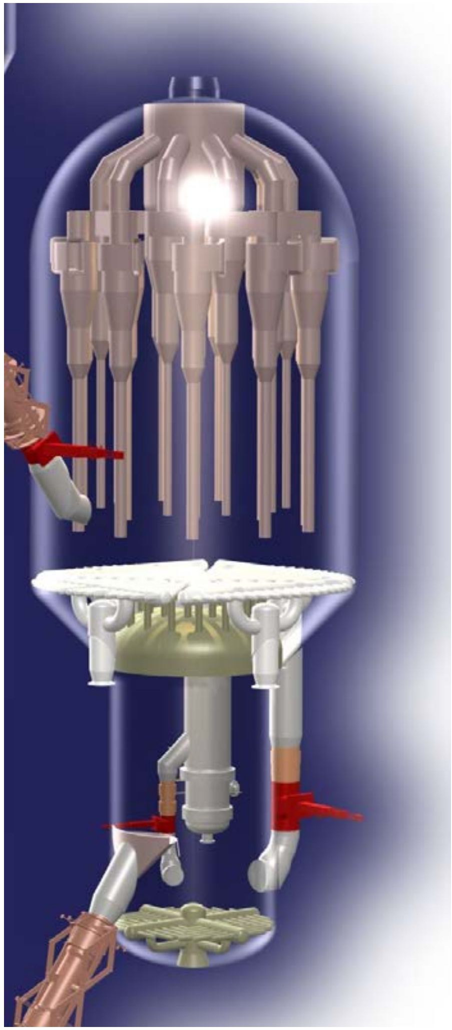
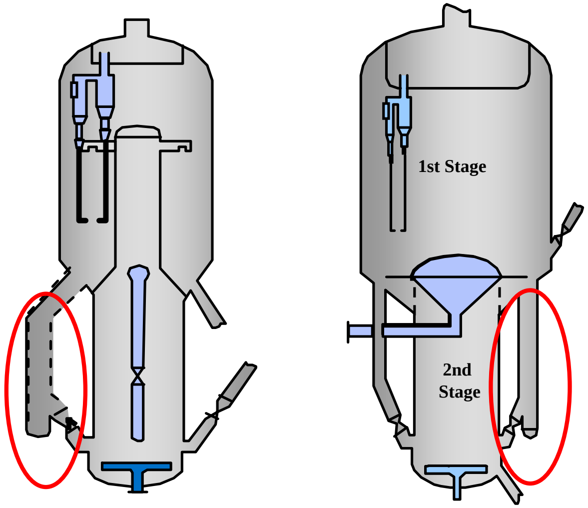
UOP Two-Stage Regenerator



- To burn high delta coke on catalyst and process highly contaminated feed
- Partial combustion operation
- Proven on feeds of ~10 Wt-% concarbon and 20,000 wppm Ni+V on catalyst
- Maximizes oxygen utilization
  - Excess oxygen in 2nd stage flue gas is used to burn coke in 1st stage
  - Minimizes air blower capacity
  - Single flue gas system
- Operator friendly
  - Result of stacked design and trouble free catalyst circulation
  - Responds well to upsets and turndown

Lowest Capex/Opex solution for contaminated feeds

Processing Heavier Feeds in an RFCC



When is a Catalyst Cooler Needed?

- Regenerator temperature too high (> 732°C / 1350°F)
- Process residue feedstocks with high Conradson Carbon (Concarbon)

What Does a Catalyst Cooler Do?

- Removes large amounts of heat from regenerator
- Generates HP steam

What is the Result?

- Regenerator temperature is reduced and independently controlled
- Cat/oil ratio increases
- Lower catalyst deactivation rate
- Improves conversion and product yields

Commercially proven technology to increase product revenues

Case Study – NE Asia FCC Unit

Revamp basis

- Operation: 53,000 BPSD VGO+AR feed in gasoline mode
- Current configuration: UOP FCC with Combustor style regenerator
- Revamp objective: Increase conversion with same feed blend

Revamp scope ***Add single UOP Catalyst Cooler***

Result

- Total annual benefit = $18 MM/yr

Approximately 1 year simple payback

Case Study – RFCC operates with one of the world's most difficult Feed

- **Design**
  - 75,000 BPD 100% AR Oman crude
  - RFCC with Two-Stage regenerator
  - 18.2 API, 6.9 wt% Con Carbon, 9 wppm Nickel, 10 wppm Vanadium
  - 9 wt% propylene

- **Commissioned in 2006**
  - Poorer quality feedstock – more contaminated than design
  - Some initial equipment and operation issues
  - 17.3 API, 8.9 wt% Con Carbon, 20 wppm Nickel, 17 wppm Vanadium
  - 8 wt% propylene
  - Up to 110% capacity on more difficult feedstock

- **Recent operation**
  - Con Carbon 8.5 to 9.5 wt%
  - Total feed metals to 44 wppm ~ 50/50 Nickel and Vanadium
  - Ecat metals around 14,000 wppm (about 7000 ppm each)

Unit has achieved C3= yield >8 wt%

Conclusions

Iranian Refiners have an incentive to process heavier feeds in RFCC Units that are heavily contaminated by metals and CCR and require a robust technology

UOP's RFCC technology solutions designed to handle feeds with a broad range of Conradson carbon and Metals

UOP's RFCC helps maximize conversion & yield selectivity; is flexible, proven & extensively commercialized

UOP's RFCC technology has successfully been proven with one of the world's most difficult feed achieving C3= yield of 8 wt.%

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Q&A